Reference: *Biol. Bull.*, 141: 485–501. (December, 1971)

PETROLISTHES TRIDENTATUS: THE DEVELOPMENT OF LARVAE FROM A PACIFIC SPECIMEN IN LABORATORY CULTURE WITH A DISCUSSION OF LARVAL CHARACTERS IN THE GENUS (CRUSTACEA: DECAPODA; PORCELLANIDAE)[1]

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Petrolisthes tridentatus Stimpson, 1858, is a diminutive porcellanid species which is apparently confined to the littoral zone on both sides of the Panamanian isthmus. In the tropical Atlantic it is found throughout the Caribbean region from the Bahama Islands to Trinidad. In the Pacific it has been collected sporadically from San Juan del Sur, Nicaragua to Isla Puna, Ecuador. Other than collection data nothing is known of the biology of the species and the larval development is completely undescribed.

The purpose of this paper is to describe the complete larval development, from hatching to megalopal stage of larvae from a Pacific specimen of *P. tridentatus*. In some other amphi-Panamanian species, the larvae obtained from adults inhabiting one side of the isthmus have differed considerably in morphological features from larvae obtained from adults on the opposite side (Gore, 1971; 1972a in press). Such may prove to be the case in *P. tridentatus* when larvae described herein are compared with those reared from an Atlantic specimen.

Materials and Methods

An ovigerous female collected from Punta Paitilla, Panama on 31 December 1968 was shipped by air to the Rosenstiel School of Marine and Atmospheric Science (RSMAS) where it was isolated in a 19 cm diameter glass bowl filled with non-flowing seawater. Hatching occurred on 8 January 1969.

A series of 120 larvae were cultured in 24-compartmented plastic trays using methods previously described for other larval cultures (Gore, 1968, 1970, 1971). Individual zoeae were placed in each compartment. Each compartment was filled with about 80 ml of filtered Biscayne Bay seawater. Salinity varied from 32–34.7‰ throughout the rearing experiment. Water was changed in the trays every day at temperatures of 20° C and higher; every other day at lower temperatures. Larvae were fed *Artemia salina* nauplii in amounts sufficient to ensure that excess nauplii remained in each compartment as noted at times of water change. The series was cultured at average temperatures of 10, 13.5 (±0.5°), 20, 24.8 (range 24–25.5° C)

[1] Scientific contribution No. 1432 from the University of Miami, Rosenstiel School of Marine and Atmospheric Science. This paper constitutes part of a dissertation submitted to the faculty of the Rosenstiel School of Marine and Atmospheric Science in partial fulfillment for the degree of Doctor of Philosophy. The work was supported by research grant no. GM-11244, from the Institute of General Medical Sciences, U. S. Department of Health, Education and Welfare, and by grant no. 7075X from the National Science Foundation.

and 29.6° (range 28–32°) C in controlled temperature units (CTU). The temperature fell for one day in the 29.6° C CTU to 26° C; this value is included in the average value computed for that temperature. These values are expressed as 5° increments in Table I. All measurements were made with a Lafayette slide micrometer. In the zoeae, carapace lengths were measured from the anterior margin of the eyes, to the points of insertion of the posterior carapace spines. In the megalopae, carapace lengths were measured from the frontal regions to the posterior edges of the carapaces; carapace widths were measured across the widest part of the carapaces. The sizes given are the arithmetic average for the number of specimens examined.

The spent female and a complete larval series are deposited in the museum of RSMAS; UMML 32: 4365, 32: 4366.

Results

Rearing experiment

Petrolisthes tridentatus hatches as a pre-zoea and remains as such for approximately two hours. Two subsequent zoeal stages and a megalopal stage follow. From the data presented in Figure 1 and Table I it is seen that the first zoeal stage lasted from three to six days; the second zoeal stage lasted from five to 11 days, and the megalopal stage lasted from seven to 17 days. Duration of the stages is apparently temperature dependent. *Petrolisthes tridentatus* is able to complete its larval life cycle in the laboratory in as little as two weeks at 29° C and usually less than a month at 20° C. Crab stages were obtained at 20° C and higher. At 29° C the larval duration was shortest but mortality was highest; less than 50% of the larvae survived to attain megalopal stage and only two crab stages were obtained. At 25° C 50% of the surviving megalopae attained crab stage. At 20° C 83% of surviving second zoeae reached megalopal stage but nearly all subsequently died. At 20° C crab stages were obtained from 11 and 17 day old megalopae. It appeared

Table I

Petrolisthes tridentatus: *duration of larval life in days at various temperatures*

		Minimum	Mean	Maximum	Total number molting to next stage
10° C		Did not progress beyond first zoeal stage			
15° C		Did not progress beyond first zoeal stage			
20° C	Zoea I	5*	5	6	23
	Zoea II	9	10*	11	21
	Megalopa	11	14	17	2
25° C	Zoea I	4*	4	4	20
	Zoea II	5	6*	6	20
	Megalopa	8	10*	13	12
30° C	Zoea I	3*	3	4	13
	Zoea II	5*	5	6	10
	Megalopa	7	No Value	8	2

* = Most frequent value.
No value = No mean due to mortality of larvae.

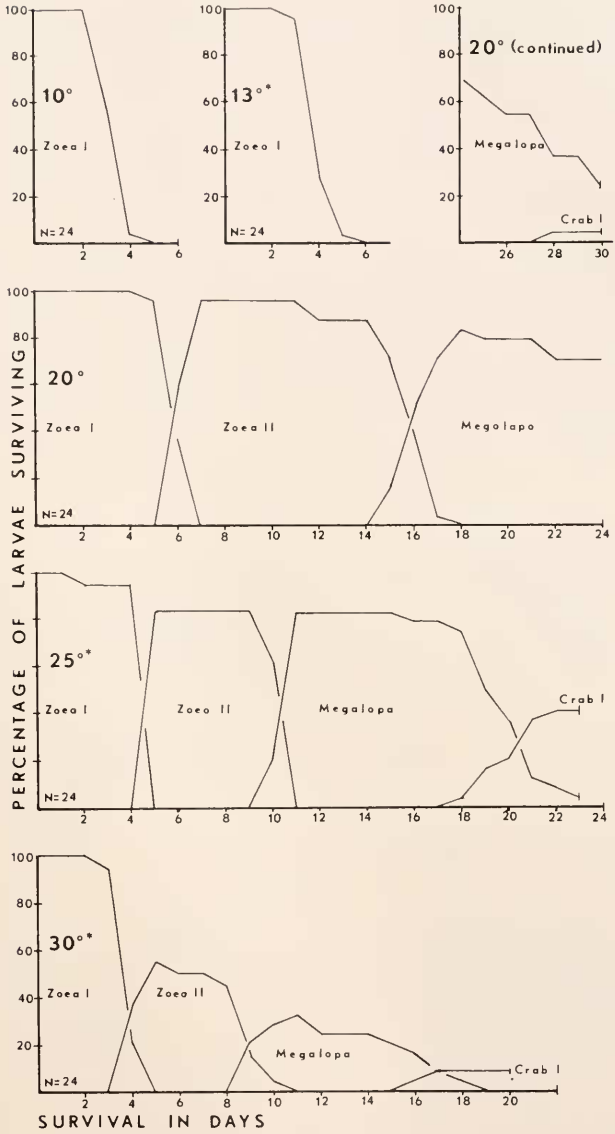

FIGURE 1. Percentage and duration of survival of larvae of *Petrolisthes tridentatus* Stimpson, reared under laboratory conditions. N is the number of larvae reared at each temperature (C°) in each series. The asterisk indicates the temperature rounded off to the closest whole number (see text for explanation).

that 25° C was the most favorable temperature in this series at which to culture larvae of this species.

Molting from stage to stage throughout the series was regular and occurred in a one to two day period, except at 20° C where the megalopal stage was reached

by zoeae in the series over a four day period. Contrary to results noted in previous studies (Gore, 1968; 1970, 1971) the molt to megalopa did not appear to be a critical period and all surviving zoeae in the series passed into this stage with no apparent difficulty.

The drop in temperature from 30 to 26° C occurred the day prior to the molt to megalopal stage. Of 11 surviving second zoeae, eight successfully completed the megalopa molt; of these, two progressed to crab stage I. All megalopae and exuviae from this temperature were examined but no noticeable variation either in morphology or number and position of major setae was noted. What effect the temperature drop had on the duration of the megalopal stage is unknown. However, two crab stages were obtained after remaining as megalopae seven and eight days, respectively. Two other megalopae died in molt to the crab stage, one after eight days and the other after nine days as a megalopa. This suggests that the ability to molt was little affected since megalopae reared at other temperatures which remained more or less constant also molted over a two to four day period.

Description of the Larvae

Zoea I

Carapace length: 1.35 mm.
Number of specimens examined: 8.

Carapace: (Fig. 2, A). Typically porcellanid; rostral spine straight or with noticeable upsweep, about 1.8 times carapace length, armed ventrally and laterally

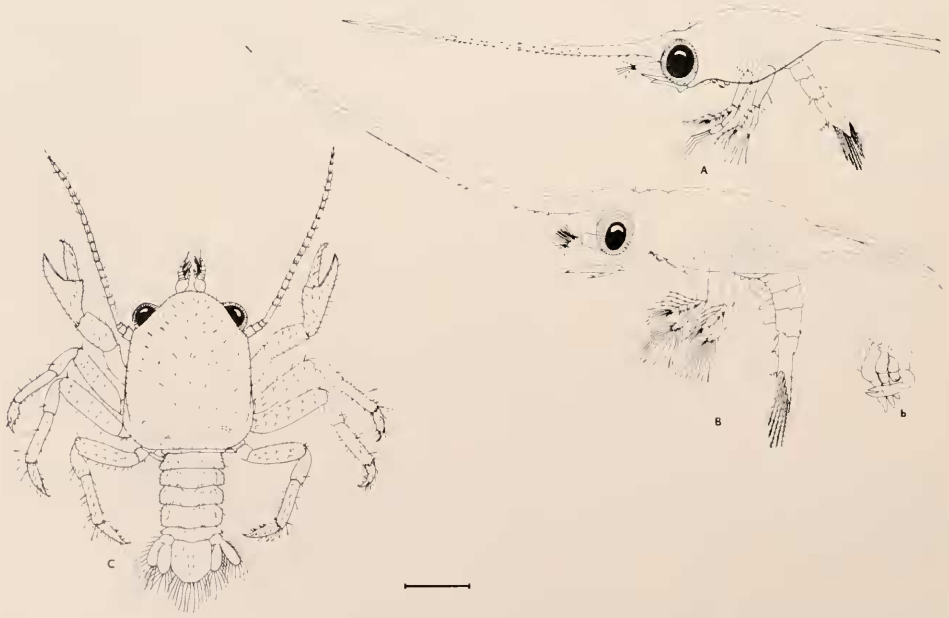

Figure 2. The zoeal and megalopal stages of *Petrolisthes tridentatus* Stimpson; A, First zoea; B, Second zoea; b, Detail of early stage pereiopods; C, Megalopa. Scale line equals 0.5 mm.

with scattered spinules, as illustrated; tip naked. Posterior carapace spines about equal to carapace length, each with three to five small nubs ventrally. Lower margin of carapace appears distinctly crenulate under high power (400 ×). Two pairs of setae dorsally above eyes; latter sessile.

Antennule: (Fig. 3, A). Simple rod; three aesthetascs (one subterminal) and three setae, as illustrated.

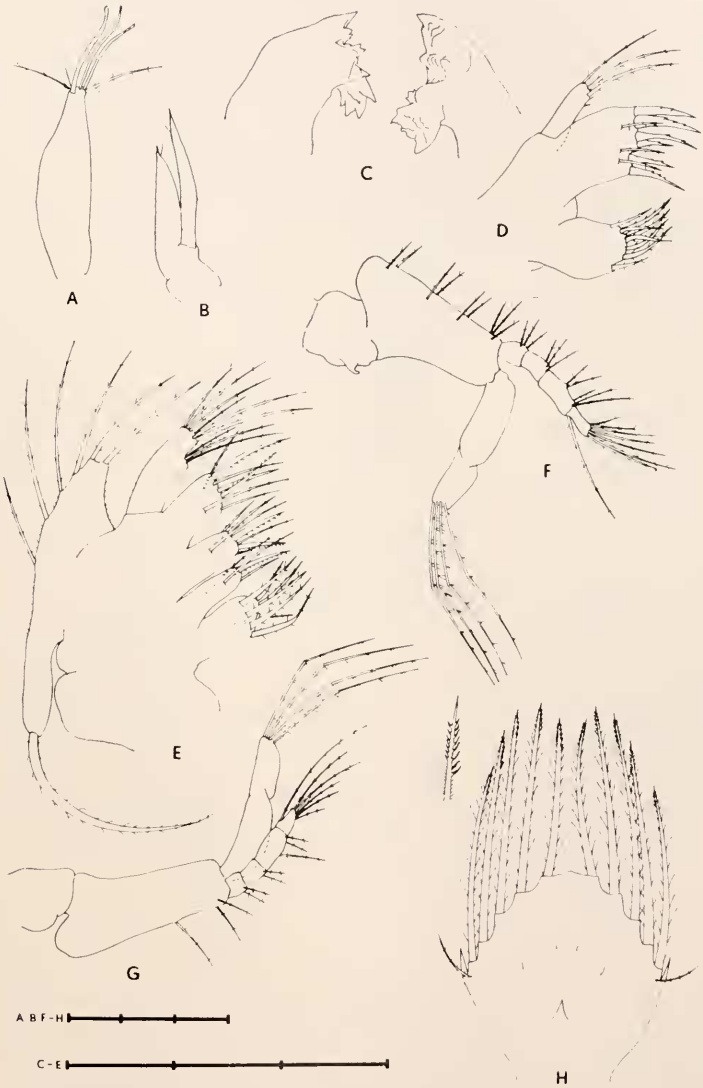

FIGURE 3. First zoeal appendages of *Petrolisthes tridentatus* Stimpson; A, Antennule; B, Antenna; C, Mandibles; D, Maxillule; E, Maxilla; F, Maxilliped 1; G, Maxilliped 2; H, Telson. Scale lines equal 0.3 mm.

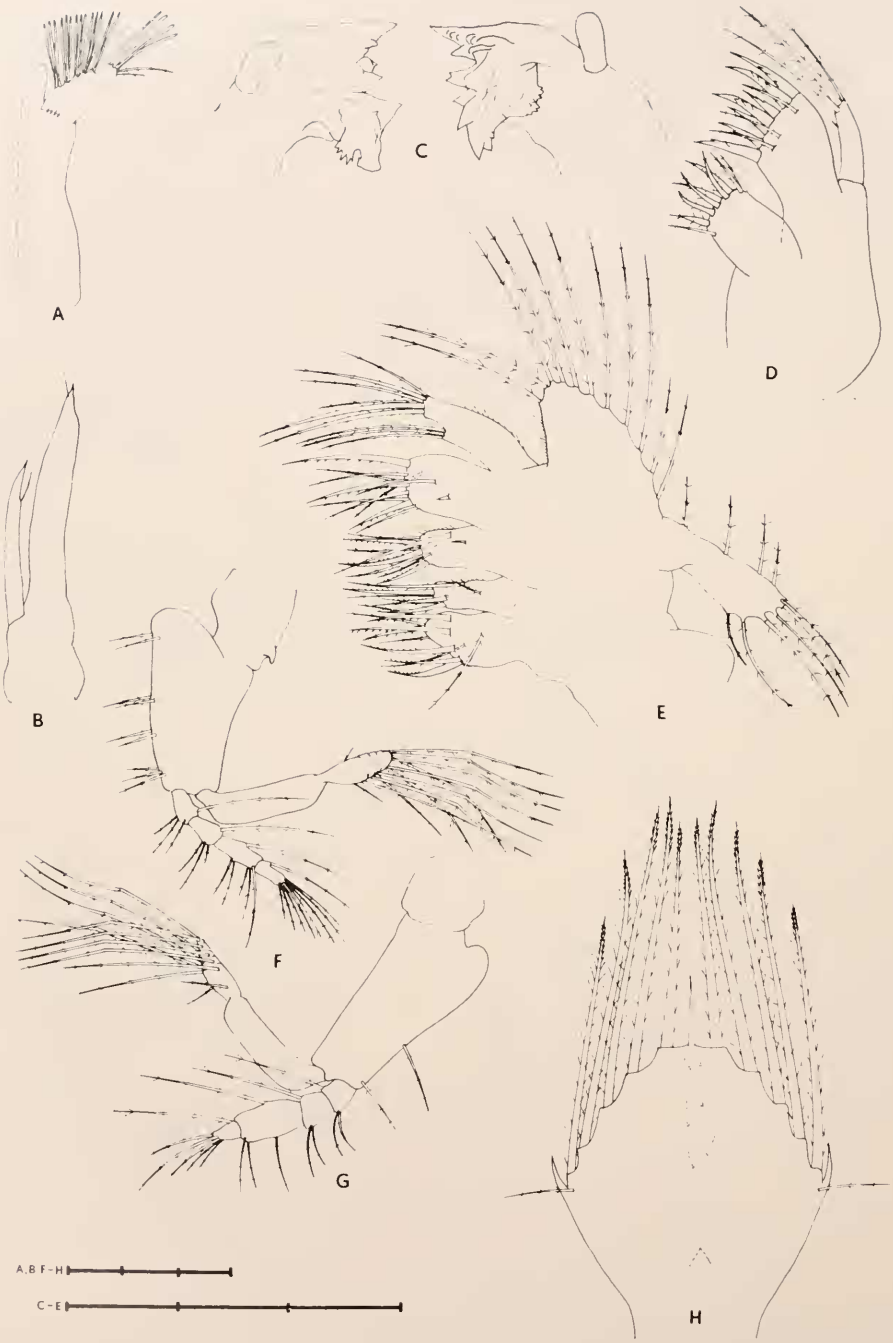

FIGURE 4.

Antenna: (Fig. 3, B). Exopodite about $\frac{1}{4}$ longer than endopodite, unarmed except for one subterminal seta; endopodite somewhat swollen, drawn into distinct spine, with one subterminal seta.

Mandibles: (Fig. 3, C). Asymmetrical processes, distinctly dentate or with prominent molar process, as shown.

Maxillule: (Fig. 3, D). Endopodite unsegmented, with three setae plus a smaller spinule subterminally. Basal endite with six spines and three setae; coxal endite with six spines and two strong setae, as illustrated.

Maxilla: (Fig. 3, E). Endopodite setae: three terminally, three subterminally, three laterally. Basal endite proximal and distal lobes each with two spines, five setae. Coxal endite proximal and distal lobes with setae as follows: four spines, three setae, and one spine, three setae. Scaphognathite with five to six setae around margin plus one long apical seta, as illustrated.

Maxilliped 1: (Fig. 3, F). Coxopodite naked but with distinct hook-like projection anteriorly, as shown. Basipodite setae 2, 2, 2, 3 progressing distally. Endopodite four-segmented, setae as follows: 3, 3, 2 + 3, 7 or rarely 8 terminally, plus one dorsal seta as shown. Exopodite two segmented, four natatory setae.

Maxilliped 2: (Fig. 3, G). Coxopodite naked. Basipodite setae 1, 2. Endopodite four-segmented, setae as follows: 2, 2, 1 + 2, 5 plus one dorsal seta. Exopodite two segmented; four natatory setae.

Maxilliped 3: Small, undistinguished buds which enlarge slightly as stage progresses. Naked.

Pereiopods: (Fig. 2, A). Amorphous buds at beginning of stage, but gradually assuming form as stage progresses. Incipient segmentation may appear.

Abdomen: (Fig. 2, A). Last three somites with lateral spines, becoming longer and stronger nearer telson.

Telson: (Fig. 3, H). Setae formula 7 + 7, last pair of plumose setae on central prominence. Plumose setae each with hook-like spines, facing inward but more developed on numbers three to five, as shown in detail. Other setae as shown. Anal spine present.

Color: Zoea transparent. Tip and distal $\frac{2}{3}$ of rostrum diffusely orange. Posterior spines transparent. Eyes silver-blue in reflected light, this color distinct. Chromatophores as follows: red, laterally on interior of foregut; yellow-red above cheliped buds on carapace; red-orange on top $\frac{1}{3}$ of basipodite; yellow on interior of intestine. Labrum, paragnath and mandible tips and maxillule ultramarine blue. Abdominal somites may reflect same blue color.

Second zoea

Carapace length: 1.55 mm.
Number of specimens examined: 10.

Carapace: (Fig. 2, B). Larger, more expanded. Rostral spine about 2 × carapace length, armed ventrally with about six irregularly placed small spinules;

FIGURE 4. Second zoeal appendages of *Petrolisthes tridentatus* Stimpson; A, Antennule; B, Antenna; C, Mandibles; D, Maxillule; E, Maxilla; F, Maxilliped 1; G, Maxilliped 2; H, Telson. Scale lines equal 0.3 mm.

remainder naked. Posterior carapace spines slightly less than carapace length; naked. Two pairs of dorsal setae as shown. Ventral margin of carapace completely smooth, without crenulation. Eyes mobile.

Antennule: (Fig. 4, A). Biramous. Exopodite fused to protopodite, rounded, about $\frac{1}{3}$ endopodite length, naked. Junction of endopodite and protopodite with four small setae. Endopodite with aesthetascs progressing distally as follows: 3, 3, 3, 3, 2, 4 terminally plus two or three setae.

Antenna: (Fig. 4, B). Exopodite about $\frac{2}{3}$ length endopodite; with single subterminal seta. Endopodite drawn into spine with one subterminal seta as illustrated.

Mandible: (Fig. 4, C). Similar to stage I, but larger and with more complex dentition. Molar and incisor processes as shown; each with distinct palp.

Maxillule: (Fig. 4, D). Endopodite a single segment, with three setae terminally; basal endite with seven spines, three setae; coxal endite with six spines, three setae.

Maxilla: (Fig. 4, E). Endopodite setae unchanged from stage I. Setae on basal endite as follows: distal lobe, three spines, seven setae, one small spine; proximal lobe, three spines, five setae, one small spine. Setae on coxal endite: distal lobe, three spines, five setae; proximal lobe, five spines, three strong and three thinner setae. Scaphognathite with 21 setae around margin, with two on the apex, well developed.

Maxilliped 1: (Fig. 4, F). Coxopodite naked, hook-like projection retained; basipodite setae 2, 2, 2, 3; endopodite setae now 3, 3, 2 + 3, 7 − 8, plus dorsal setae as illustrated. Exopodite two-segmented with a total of 12 setae.

Maxilliped 2: (Fig. 4, G). Coxopodite naked; basipodite setae 1, 2; endopodite setae 2, 2, 1 + 2, 5, plus dorsal setae on each segment; as illustrated. Exopodite two-segmented; 12 setae as illustrated.

Maxilliped 3: More developed than previous stage, with endopodite and exopodite more elongate.

Pereiopods: (Fig. 2, b). As illustrated, well developed appendages; segmentation nearly complete. Fifth pereiopod tucked between cheliped and walking leg 1, as illustrated.

Abdomen: (Fig. 2, B). Little changed from first stage except larger; lateral spines remain. Pleopods on segments 2, 3, 4, 5.

Telson: (Fig. 4, H). Fifth pair of plumose setae remain on telson prominence but median spine added. Other setae and armature on long plumose setae as in stage I.

Color: Similar to stage I. Chromatophores as in stage I. Blue color on mouthparts and abdomen still quite intense.

Megalopa

Number of specimens examined: 10.
Carapace length × width: 2.25 × 1.25 mm.

Carapace: (Fig. 2, C). Truncately oval, moderately inflated, smooth to very lightly punctate, sparsely covered with hairs. Frontal region strongly deflexed, not trilobate or tridentate, rounded anteriorly, sparsely covered with hairs. Posterior orbital angle without teeth or spines, rounded. This stage bears little re-

semblance to an adult. However, some first crab stages exhibit distinctly trilobate frontal region as seen in adult crabs.

Antennule: (Fig. 5, A). Biramous; peduncle three-segmented, basal segment enlarged and inflated with one or two small teeth on outer anterior margin and setae as shown; third segment much inflated with one or two setae. Lower ramus indistinctly seven-segmented, six distinctly so, proximal segment incompletely; aesthetascs on segments two through five in the following sequence of rows and numbers: one row (6), two rows (6, 3 − 4 + 2 setae), two rows (3, 2 + 1 seta), one row (3). Other setae on tip as illustrated. Upper ramus of three distinct segments, but last incompletely divided as to suggest four segments; setae appear as illustrated.

Antenna: (Fig. 5, B). Peduncle three-segmented; flagellum with about three fused segments plus 18 − 22 shorter segments each with about six setae around distal articulation; terminal segment with five long setae as illustrated.

Mandible: (Fig. 5, C). Scoop-shaped processes, appearing heavily chitinized on upper surface of blade. Anterior edge of each appears as illustrated. Each has three-segmented palp: first segment with two spines on outer edge, last with about nine short stout spines.

Maxillule: (Fig. 5, D). Endopodite unsegmented, swollen at base; a short spine and a single seta appears. Coxal endite, lower portion, extended into rounded lobe fringed with fine hairs; a single long seta near its base. Basal endite with shorter seta about midway down its length. Coxal lobe with 11–12 spines, 7 setae. Basal endite with 12–13 short spines, 10 setae.

Maxilla: (Fig. 5, E). Endopodite unsegmented; 2 long setae near tip, one short seta terminally. Coxal and basal lobes heavily spinose and setose, processes difficult to count. Coxal endite with processes on proximal and distal lobes as follows: at least 10 terminally + about 16 encircling lobe; 5 terminally, 7 progressing down the side as illustrated. Basal endite proximal and distal lobes with processes as follows: 12 terminally, 3 to 4 beneath; about 25–28 processes; short stubby spines on lateral surface of each as illustrated. Scaphognathite with about 44 setae around margin plus smaller hairs on lateral surface as illustrated.

Maxilliped 1: (Fig. 5, F). Endopodite and exopodite appear almost unchitinized; 4 short terminal spines plus setae as illustrated on former, 7–8 terminal and 4 lateral setae on latter. Protopodite with about 24 setae on the basal endite and 8 terminal setae on the coxal endite plus others laterally as illustrated.

Maxilliped 2: (Fig. 5, G). Exopodite two-segmented six to eight terminal setae and three lateral spines as shown. Endopodite four-segmented, last two segments heavily spinose, with at least 12 and 10 spines, respectively, first two segments each with about 5 setae placed as illustrated. Basipodite and coxopodite with setae as illustrated.

Maxilliped 3: (Fig. 5, H). Coxopodite with 2 strong distinct spines plus additional setae. Basipodite with setae as shown. Exopodite with three terminal, one lateral, setae. Endopodite five-segmented, first two with lateral blade-like projections. Ischium with total of 12 setae; merus with 13 long plumose setae; carpus with six strong dagger-like spines, 12 long plumose setae; propodus with 8 strong dagger-like spines, nine long plumose setae; dactyl with four strong dagger-like spines and nine long plumose setae. Other smaller setae appear as illustrated.

FIGURE 5. Megalopal sensory and feeding appendages of *Petrolisthes tridentatus* Stimpson; A, Antennule; B, Antenna; C, Mandibles; D, Maxillule; E, Maxilla; F, Maxilliped 1; G, Maxilliped 2; H, Maxilliped 3; h, Spine position on maxilliped 3. Not all setae are completely figured. Scale lines equal 0.3 mm.

Pereiopods: (Figs. 2, C; 6, A, B, E). Chelipeds not overly large, flattened, somewhat subequal, covered with many setae. Moveable finger of each with two distinct spines laterally as illustrated (Figure 6, E). Carpus of chelipeds appearing unarmed but under high magnification about three very small spines appear on interior edge; postero-distal edge with one or two small spinules. Dorsal margin of propodus next to articulation of dactylus may have two hooked spinules. Merus, carpus and propodus of walking legs as illustrated; merus with lateral setae projecting from rugae as illustrated (Figure 6, A), plus about six very small spinules on dorsal margin; one large distinct spine dorso-distally; carpus with setae as shown plus distinct long spine laterally; propodus with two strong spines placed more or less laterally plus five spines ventrally, in addition to long and short setae illustrated; dactylus with setae and spinules as shown. Pereiopod 5 (Figure 6, B) as illustrated, each with five to six long serrate scythe-like setae.

Pleopods: (Fig. 6, C, D). Occur on segments two-five; biramous, becoming

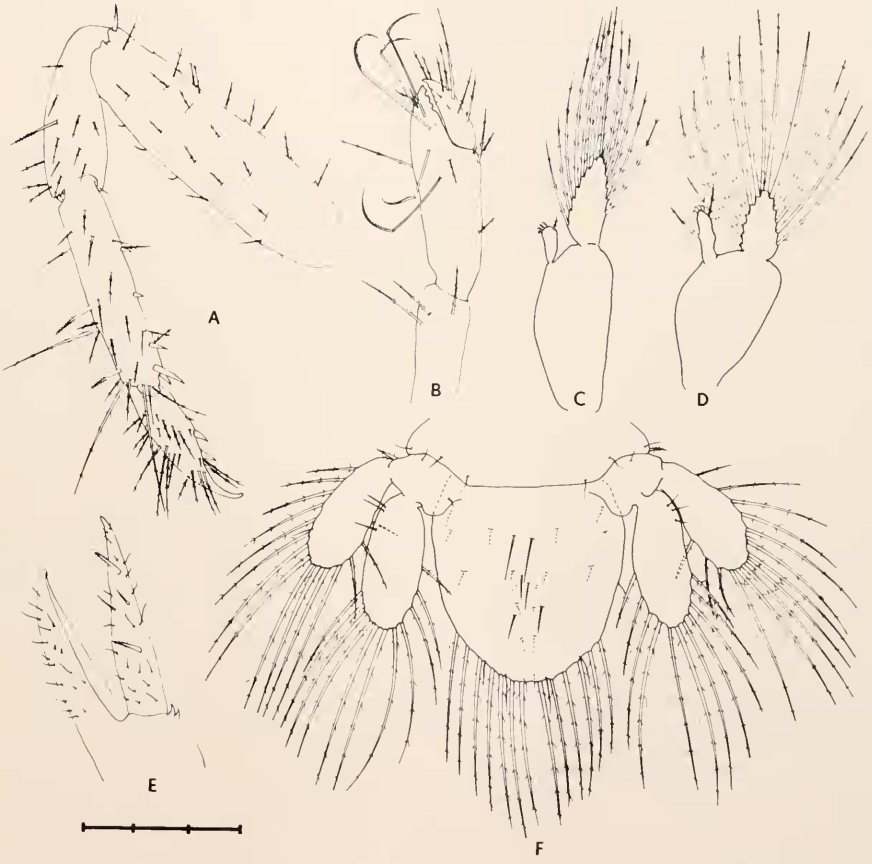

FIGURE 6. Megalopal locomotory appendages and tail fan of *Petrolisthes tridentatus* Stimpson A, Pereiopod 2; B, Pereiopod 5; C, Pleopod 1; D, Pleopod 4; E, Detail of chela; F, Tail fan (ventral view). Scale lines equal 0.3 mm.

wider toward telson. Setae on exopodites most often 13, occasionally 14. Endopodite setae progressing toward telson usually 0, 0, 1, 2, but may vary from 0 to 2 on last two pleopods; all developed with appendix interna.

Abdomen: (Fig. 2, C). Pleura with numerous long setae as shown.

Tail fan: (Fig. 6, F). Six to seven long plumose setae interspersed with two or three shorter setae on each side of telson as shown; numbers not consistent. Uropods biramous, exopodites with about 14 to 16 setae; endopodites with 11 setae; around outer edges. Telson plate with two long distinct setae ventrally plus others as illustrated.

Color: Megalopa transparent. Eyes a distinct sea-foam green. Red chromatophores placed as follows: dorsally next to articulation of moveable finger on propodus of cheliped; dorsally near articulation of carpus with propodus of same; antero-dorsally and ventrally on merus of cheliped. On carapace as follows: frontal region with one just interior to each eye plus one on interior of carapace; lateral margins with about six on each side; hepatic region each with large expanded chromatophore; interiorly in gastric region with very large expanded chromatophore. A small red chromatophore ventrally on second abdominal somite; another on articulation of carpus and propodus of third maxilliped.

Discussion

The zoeae of *Petrolisthes tridentatus* may be recognized in the plankton by the following features: the lower margin of the carapace is distinctly crenulate in the first zoea, the rostral spine in both zoeal stages is relatively short compared to those seen in other porcellanid larvae, and is heavily armed in zoea I and sparsely so in zoea II, there are lateral spines on the last three abdominal somites, and the coxopodite of maxilliped 1 has a noticeable hook-like projection anteriorly. In live specimens the distinct silver-blue color of the eyes and the chromatophore color and position in both stages may aid in identification. The armature on the tips of the plumose setae of the telson is an additional feature which may be useful, but must be used with care since this feature is also seen in other *Petrolisthes* larvae, and in larvae of the genus *Pachycheles*.

The megalopal stage, while definitely porcellanid in character (*e.g.,* reduced fifth legs) does not much resemble the adult. The frontal region is not trilobate in this stage, but usually becomes so upon molt to first crab stage. In addition, there are three small spines anteriorly on the margin of the carpus whereas in the adult the margin is unarmed. Nevertheless, the megalopal stage of *P. tridentatus* has certain features which should enable one to recognize it in plankton collections. The carpus and dactylus of the cheliped, and the merus, carpus and propodus of the walking legs all have at least one strong distinct spine distally; the dactyl of the cheliped has two spines on the lateral surface while the propodus of each walking leg has these spines more or less dorso-laterally. The walking legs also possess several very long setae, as do the dorso-lateral surfaces of each abdominal pleuron. Features on the mouthparts include two distinct spines on the coxopodite of maxilliped 3, the large numbers of setae on the merus and carpus of this appendage, the three lateral spines on the exopodite of maxilliped 2, the single long seta at the base of

both the coxal and basal endites of the maxillule, and the spine and seta on the endopodite of the same. Unfortunately, observation of these features requires dissection of the mouthparts, making such features less useful than the overall morphological characters previously described.

In live megalopae the large distinct chromatophore on the gastric region, resembling a splash of red ink, and the smaller chromatophores along the lateral margin should make this species easily identifiable in the plankton.

The zoeal stages of *P. tridentatus* have the fifth pair of telson setae on the central prominence in stage I, and a median spine in this position in stage II. Thus, they conform exactly to Lebour's (1943) classification of such larvae as members of the *Petrolisthes*-group. In addition, the mandibles have a palp in stage II zoeae. This feature appears to be limited to larvae which belong to the *Petrolisthes*-group of larvae (but see below).

The larvae of *P. tridentatus* when compared with larvae of other species of *Petrolisthes* exhibit many features in common. These are summarized as far as available data permit in Table II (see Sankolli, 1967; Shenoy and Sankolli, 1967; Gohar and Al Kholy, 1957; Gore, 1970). Although some descriptions of the larvae which are compared in the table lack much needed detail it is still possible to make several generalizations concerning the larvae of the genus *Petrolisthes* which conform to Lebour's grouping. The larvae of *Petrolisthes platymerus,* and both *P. elongatus* and *P. novaezelandiae* (see Wear, 1964a, 1964b) are excluded since they do not fit into Lebour's category. The first two species have already been compared in a previous study and a third grouping, the *P. platymerus* group, has been tentatively suggested (Gore, 1972b, in press). Larvae in this third grouping, like those in the *Petrolisthes*-group, also possess a mandibular palp in the second zoeal stage. *Petrolisthes lamarckii* and *P. rufescens* (Table II) are species very closely related to each other which occur in the Indo-Pacific region (Haig, 1964). *Petrolisthes armatus,* a species recorded from tropical west Africa and the Americas has also been alleged to occur in the Indo-Pacific but its occurrence there is doubtful. *P. armatus* is related to *P. asiaticus* which is found in the Indo-Pacific and both of these species were synonymized at one time under *P. lamarckii* (see Haig, 1960, page 54), but all are now considered to be distinct species.

Petrolisthes boscii, another Indo-Pacific species, is not as closely related to the three preceding species, nor is *P. tridentatus.*

As indicated in Table II, the larvae of all these species share most of the following features in the first zoeal stage: antennule with three aesthetascs, three setae; antennal exopodite longer ($\frac{1}{4}$ to $2\times$) than endopodite, with one to three thin setae; mandibles without palps; maxillulary endites each with six spines, and basal endite with three, coxal endite with one to three setae, endopodite with three to five setae, often with one small subterminal seta; maxillary endopodite with 3, 2, 3, or 3, 3, 3, setae, next three endites with no more than seven processes each, coxal proximal lobe with four processes, and scaphognathite with five to seven setae.

The thoracic appendages show more variability. Setation of the basipodites differs in each of the species, as does that of the endopodites of the first maxilliped. It is interesting to note, however, that if the dorsal seta (1) on the third segment is moved to the terminal position in *P. boscii* and *P. lamarckii* then a setae formula

TABLE II

Comparison of zoeal characters in five species of Petrolisthes

Zoea I	*P. tridentatus*	*P. armatus*[1]	*P. boscii*[2]	*P. lamarckii*[3]	*P. rufescens*[4]
Antennule	3 aesthetascs 3 setae	3 aesthetascs 3 setae 2–3 setae (P)	3 aesthetascs 3 setae	3 aesthetascs 3 setae	?4 aesthetascs ?3 setae
Antenna					
Exopodite	$\frac{1}{4}$ >endopodite 1 seta	2 × endopodite 2 setae $\frac{1}{3}$ >endopodite (P)	$\frac{1}{4}$ >endopodite 3 setae	2 × endopodite 3 setae	$\frac{2}{3}$ >endopodite "few hairs"
Mandible	No palp	No palp	No palp	No palp	No palp
Maxillule					
Endopodite	3 setae + 1 subterminally	3 setae + 1 subterminally	5 setae + 1 subterminally	4 setae	3 setae
Bsl. endite	6 spines	6 spines	6 spines	5 spines	6? spines
	3 setae	3 setae	3 setae	3 setae	
Cox. endite	6 spines	6 spines (5 P)	6 spines	6 spines	6?spines
	2 setae	1 setae (2 P)	1 seta	1 seta	?3 setae
Maxilla					
Endopodite	3,3,3, setae	3,2,3, setae	3,3,3, setae*	3,3,3, setae	3,2, − setae
Bsl. endite	7,7, processes	7,7, processes	5,6 processes*	7,5 processes*	5,4 processes*
Cox. endite	4,7 processes	4,7, processes	3,4, processes*	4,5, processes*	4,6, processes*
Scaphognath.	5 − 6 setae	5 setae	7 setae	7 setae	4 setae
Maxilliped 1					
Basipodite	2,2,2,3, setae	1,2,2,3, setae	2,1,1,3, setae*	1,1,1,3, setae*	? 2, 1 setae
Endopodite	3,3,2+3, 7+I	3,3,2+4, 9+I 3,3,2+3, 7+1 (P)	3,3,2+4+I, 7–8*	3,3,2+4+I, 7	1,0,3,4, No dorsal seta*
Maxilliped 1					
Expodite	4 natatory	4 natatory	4 natatory*	4 natatory*	4+2 "short hairs"
Maxilliped 2					
Basipodite	1,2 setae	1,1 setae	1,2? setae	1 seta	? None
Endopodite	2,2,1+2, 5+I	2,2,1+2, 5+1	2,2,3+I, 5	1,2,4,5 ?2,2,1+2, 5+I†	3,2,1+3, 4* No dorsal seta*
Exopodite	4 natatory	4 natatory	4 natatory	4 natatory	4 natatory
Maxilliped 3	Small undistinguished buds	Bifid lobe 1–2 setae occasionally (P:no setae)	"biramous buds"	"biramous . . . rudimentary"	"rudiments"
Pereiopods	Amorphous buds	Undifferentiated buds	"Rudiments . . . (as) small buds"	". . . present as small buds"	"rudiments"
Abdomen	Somites 3, 4, 5 with lateral spine	Somites 4, 5 with lateral spine	Somites 4, 5 with lateral spine	Somites 4, 5 with "sharp" spine	Somites 4, 5 with lateral spine
Telson	5th pair setae on prominence; 3–5 with more prominent hooks	5th pair setae on prominence all armed with distinct spinules	5th pair setae on prominence; all armed with "tooth-like spines"	5th pair setae on prominence; all armed with "tooth-like spines"	5th pair setae on prominence?
Zoea II					
Antennule					
Exopodites	3,3,3,3,2,4, +2–3 setae	4,5,3,3,2,3, +2 setae 4,4,3,3,2,3, +2 setae (P)	2,2,2,2,3, + 3 setae	No description available	?10*
Endopodite	4 setae at jct. protopodite	4 setae at jct. protopodite	3-4 setae at jct. protopodite		4 setae at jct. protopodite
Protopodite		1 lateral, 2 basal setae	1 lateral seta		
Antenna					
Exopodite	$\frac{2}{3}$ endopodite	$\frac{1}{2}$ endopodite $\frac{2}{3}$ endopodite (P)	$\frac{1}{2}$ endopodite		$\frac{1}{2}$ endopodite
	1 seta	1 − 0 seta	4 setae*		No setae
Mandible	Palp present	Palp present	Palp present		Palp present
Maxillule					
Endopodite	3 setae	3 setae	4 setae		3 setae
Bsl. endite	7 spines	7 spines	?7 spines		?8 processes*
	3 setae	3 setae	?3 setae		
Cox. endite	6 spines	6 spines	?6 spines		6 spines
	3 setae	3 setae	?4 setae		?1 setae*
Maxilla					
Endopodite	3,3,3, setae	3,2,3, setae	3,3,3,?2 setae		5,3, setae?
Bsl. endite	10,8 processes	9,8 processes 10,9 processes (P)	9,11 processes?		6,9 processes
Cox. endite	8,11 processes	6–8, 8 processes 4,8 processes (P)	5,16 processes?		4,9 processes No specific description
Scaphognathite	19+2 apical setae	16–20+1 apical seta 14–16+1 apical seta (P)	24+2 apical setae		14–18+2 apical setae

Table II—(continued)

Zoea I	*P. tridentatus*	*P. armatus*[1]	*P. boscii*[2]	*P. lamarckii*[3]	*P. rufescens*[4]
Maxilliped 1					
Basipodite	2,2,2,3 setae	1,1,2,3, setae 1,2,2,3 (P)	2,1,1,3, setae		−,1,1,2? setae*
Endopodite	3+1, 3+1, 2+3 +1,7−8+1	3+1,3+1,2+5 +1,11+1 3+1,3+1,2+3 +1,9+1 (P)	3+1,0+1,3+1 3+1,4+1†		1,1,1+1,3+1,10†
Maxilliped 2					
Basipodite	1,2 setae	1,1 setae	1,2 setae		0? setae
Endopodite	2+1,2+1,1+2 +1,5+1	2+1,2+1,1+2 +1,5+1	2+1,1+1,1+1 +1,4+1†		−,1,1+1,4†
Exopodite	12 setae	12–15 setae	10 setae		12 setae
Maxilliped 3	All more or less rudimentary but increase in size				Rudimentary
Pereiopods	All more or less developed with segmentation seen				"Not functional"
Pleopods	Somites 2, 3, 4, 5	Somites 2, 3, 4, 5	Somites 2, 3, 4, 5		Somites 2, 3, 4, 5
Telson	Median spine present on central prominence of telson		Median "plumose seta" (= spine) on prominence		Median spine present on central prominence, +2 setae

Data from [1]Gore, 1970; and 1972a (in press); [2] Shenoy and Sankolli, 1967; [3] Sankolli, 1967; [4] Gohar and Al Kholy, 1957.

(P) = data of larvae from Pacific specimens.

* = No specific description given, data derived from illustrations.

† = Illustration unclear, most probable situation indicated.

of 3, 3, 2 + 3 − 4, 7 − 9 + 1, is seen. Similarly, in the second maxilliped a formula of 2, 2, 1 + 2, 5 + 1, is seen. This would then conform to the formula seen in *P. armatus* and *P. tridentatus*, and might be the more probable situation.

Recurring features in the second zoeal stage of the genus *Petrolisthes* are less clear (because of the limitation in data) but the following appear to be more or less consistent; antennule with five rows of aesthetascs plus three or four terminally, four small setae at the junction of the protopodite with the exopodite, usually one long seta just below the endopodite and two short setae on the medial projection of the protopodite; antennal exopodites are now shorter ($\frac{1}{2}$–$\frac{2}{3}$) endopodites; mandibles have a palp; maxillulary endites add one to three processes on each; processes on maxillary endites increase by one to four; maxillipedal endopodites add one dorsal seta to each segment plus one or more setae terminally; pleopods appear on somites 2, 3, 4, 5; a median spine occurs on the central prominence of the telson.

Many of these same features occur in larvae of *Pachycheles* and *Megalobrachium*, both members of the *Petrolisthes*-group. *Pachycheles* zoeae can be distinguished from known *Petrolisthes* and *Megalobrachium* zoeae by the antennal exopodite which, in the first stage, is armed laterally down its length with three to four small spines in a row (see Knight, 1966; Boschi, Scelzo and Goldstein, 1967; Sankolli, 1967; Gore, 1971). In *Petrolisthes* and *Megalobrachium* only fine hairs occur here. Both *Petrolisthes* and *Pachycheles* possess hook-like spinules on the tips of the elongate telson setae in both zoeal stages while *Megalobrachium* does not. These spinules occur on all five pairs of setae to a greater or lesser degree in known *Petrolisthes* larvae and in the first zoeal stage of *Pachycheles natalensis* (Sankolli, 1967), but only on the first two pairs of setae in other *Pachycheles* larvae. Since *P. natalensis* occurs in the Indo-Pacific it cannot be confused with *Megalobrachium*, a genus endemic to the New World; and it is separated from known *Petrolisthes* larvae by the telson setae features used in conjunction with antennal exopodite characteristics.

Summary

Petrolisthes tridentatus is a shallow water amphi-Panamanian porcellanid crab. The complete development from hatching through meglopal stage for larvae obtained from a Pacific specimen is described and illustrated. The larval development under laboratory conditions consists of a pre-zoeal stage lasting about two hours, followed by two zoeal stages lasting from three to six and five to 11 days, respectively. The megalopal stage lasts from seven to 17 days. Data from the larvae cultured at different temperatures indicate that *P. tridentatus* can complete its life cycle under laboratory conditions in as little as two weeks at 29° C, and usually in less than a month at 20° C.

The zoeal and megalopal stages of *P. tridentatus* exhibit several features, notably on the coxopodite of maxilliped 1, the last three abdominal somites, and the elongate plumose processes on the telson in the zoeal stages, and on the distal segments of the pereiopods in the megalopal stage which may allow these stages to be recognized in the plankton. *P. tridentatus* zoeae also exhibit telsonic features which clearly place the larvae in the *Petrolisthes*-group of larvae established by Lebour.

The zoeae of *P. tridentatus* have several features in common with other known *Petrolisthes* spp. larvae. These features are discussed and compared in an attempt to provisionally delineate larval characters at the generic level. These characters are differentiated from those known to occur in larvae of *Pachycheles* and *Megalobrachium,* the other members presently belonging to the *Petrolisthes*-group of larvae.

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